Polymer Waveguide Output Couplers

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Researchers are currently investigating numerous applications of optics to information processing problems. Integrated optics, in particular, is being researched as a mechanism to increase information exchange speeds and capacities beyond electronic limitations. To accomplish these increases, optical devices are interspersed with electronic devices. This allows designers to take maximum advantage of the benefits from both optical and electronic technologies. Integrating optical circuits with electronic circuits requires small feature sizes, high efficiency to minimize power consumption, conversion between optical and electrical signals, nonplanar interconnections, and manufacturing compatibility.

To address the problem of nonplanar interconnections fabricated in materials compatible with electronic fabrication technology, waveguide output couplers were designed and fabricated in Norland Optical Adhesive (NOA) No. 81 and AMOCO Ultradel 9020D polyimide. The output couplers were implemented using periodic relief gratings (fig. 115) on a planar waveguide (fig. 116). Design theory of the couplers was based on the perturbation approach. Coupling of light from waveguide propagation modes to output radiation modes can be described by coupled mode theory and the transmission line approximation of the perturbed area (grating structure). Using these concepts, gratings were accurately designed to output a minimum number of modes at desired output angles.

Waveguide couplers were fabricated and analyzed for structural accuracy, output-beam accuracy, and output efficiency. The results for the two different materials are compared. Applications for these couplers include data bus and clock distribution system interfaces requiring coupling to out-of-plane detectors.

This research was conducted as a joint effort between MSFC and the U.S. Army Missile Command Weapons Sciences Directorate Research, Development, and Engineering Center. The research was initiated in March 1994 and concluded in March 1996. The research was supported by MSFC under a Center Director's Discretionary Fund activity in the area of binary optics.

The objective of this effort was to design and produce waveguide couplers for efficient optical coupling between nonplanar devices. Couplers of this nature will be required for effective optical interconnections between electronic components. Rectangular relief diffraction gratings were investigated as a method of providing efficient nonplanar coupling. In addition, efficient integration of optical and electronic components requires compatible material and fabrication processes. Optical polymers were evaluated for electronic component compatibility, fabrication repeatability, and optical device efficiency.

Gratings were fabricated in both the NOA and Amoco materials with 1 μm feature sizes. Figure 117 illustrates the expected output angles for the fundamental mode of either material.

Several characteristics of the fabricated couplers were evaluated. These characteristics include waveguide thickness, output power, number of output angles, near-field output profile, and the far-field output profile. Fundamental mode coupling

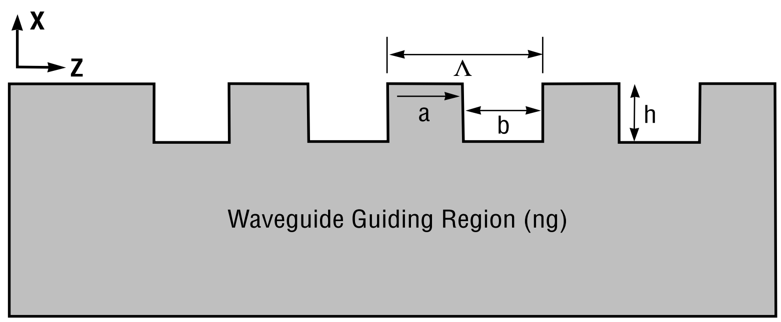

FIGURE 115.—Basic relief grating structure.

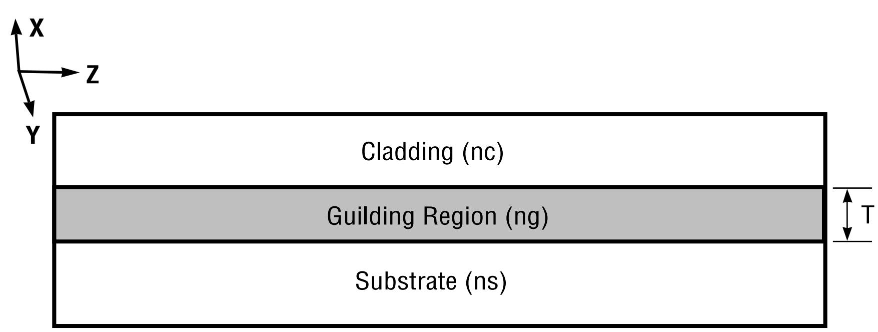

FIGURE 116.—Planar waveguide structure.

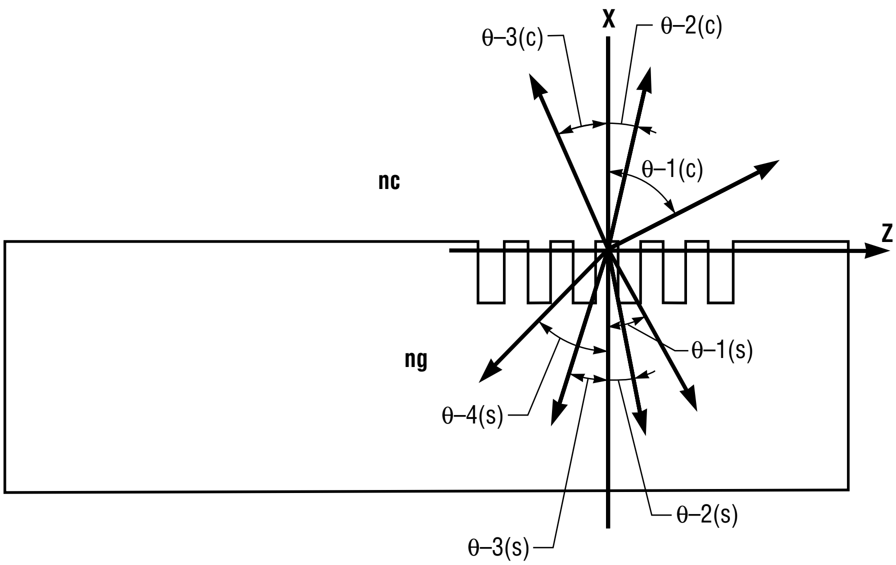

FIGURE 117.—Coupler output angles for the fundamental waveguide mode.

efficiencies of 69.39 percent and 74.28 percent were measured for the NOA and Amoco materials, respectively.[1]

Preliminary results of this research were presented at the 1995 Society for Photo-optical Instrumentation Engineers (SPIE) International Symposium in San Diego, California. These results were published in the conference proceedings.[2]

There are several applications which could utilize coupler designs based on this approach. Among these are optical interconnections of various types and optical gyroscopes. Using optical coupling in systems provides several benefits both to NASA and commercial applications. Using the results of this research, efficient couplers can be designed yielding high bandwidth, electromagnetic interference (EMI) immunity, negligible beam interference, large fanout, higher interconnection complexity, and ground loop isolation. These characteristics may be used to simplify systems and reduce weight of both space and other commercial applications.

[1]Watson, M.D.: “Polymer Waveguide Output Couplers”. Master’s Thesis, University of Alabama in Huntsville, 1996.

[2]Watson, M.D.; Abushagur, M.; Ashley, P.; Johnson-Cole, H.: Proceedings, SPIE International Symposium, July 1995. Application and Theory of Periodic Structures, vol. 2532, pp. 131–140.

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Biographical Sketches: Michael D. Watson is the lead engineer for HOSC Remote Services Systems. He has been a member of the Mission Operations Laboratory since April 1989. Currently, he is responsible for defining, designing, and developing remote services systems and concepts for the Huntsville Operations Support Center (HOSC). These responsibilities address services for the Spacelab, Space Shuttle, *International Space Station*, and Advanced X-Ray Astrophysics Facility (AXAF). Watson earned a bachelor of science in electrical engineering from the University of Kentucky in 1987 and a master of science in engineering in the Electrical and Computer Engineering Department from the University of Alabama in Huntsville in 1996.

Dr. Helen J. Cole is an optical physicist in the Electro-optics Branch of MSFC’s Astrionics Laboratory. She has been a member of that lab since May of 1991. She is currently responsible for diffractive optics research efforts as they relate to MSFC’s participation in a 2-1/2-year DARPA-sponsored technology reinvestment project (TRP) activity. MSFC and MICOM are partners with four industrial participants that will consider commercialization issues, and space and military insertion points for the technology. Cole holds a B.S. in mechanical engineering from the University of Wisconsin, and a Ph.D. in mechanical engineering from the University of Alabama in Huntsville.